MOTOROLA FUZZY LOGIC SEMINAR

MOTOROLA FUZZY LOGIC
The advantages are clear

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Semiconductor Products Sector

Advanced Microcontrollers

Motorola Semiconductor Products, Canada

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Motorola Fuzzy Logic

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Fuzzy Logic Seminar

- What is Fuzzy Logic ?
- Fuzzy Logic Fundamentals
- Fuzzy Logic Example
- Fuzzy Logic Design Methodology
- Fuzzy Logic Development Tools
- Fuzzy Logic Applications
- Demonstration
- Summary and Doorprize Draw

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Simple Tasks (for us) are Difficult (for computers)

Tasks that are simple even to a child are extremely complex to describe using traditional computing techniques :

For example,

- Balancing a Stick
- Recognising Handwriting
- Parking a car

There is a better way, a framework which can mimic human intuition.

What is Fuzzy Logic ?

Fuzzy = Imprecise, like our natural language adjectives

Fuzzy Logic was invented in 1965 by Professor Lotfi Zadeh at UC Berkeley to help the inexact socio-economic research. It is an extension of the classical set theory and is supported by rigorous mathematics.

There is nothing fuzzy about Fuzzy Logic !

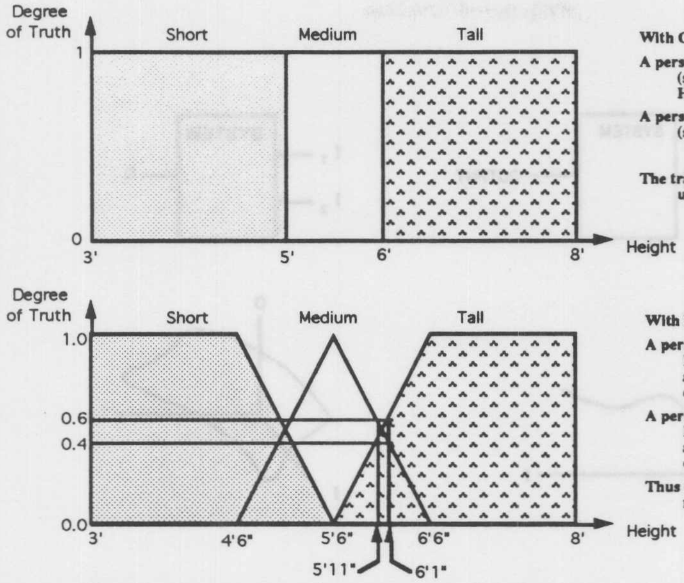
Unfortunately, we (engineers in North America) have not embraced Fuzzy Logic extensively because of

- our demand for precision, and
- the negative connotation we attach to the word *fuzzy*.

But engineers in the East (Japan & China) have.

It is estimated by Motorola that by 1995, over 50% of all Microcontroller applications will utilize Fuzzy Logic.

Fuzzy Logic is More Natural



With Conventional Logic :

A person of height a touch less than 6' (say 5'11") is still only "Medium Height", but

A person of height just a touch over 6' (say, 6'1") will be called "Tall"

The transition is very sharp and un-natural.

With Fuzzy Logic :

A person of height of 5'11" is "Medium Height" with Degree of Truth of 0.6 and "Tall" with a Degree of Truth of 0.4, and

A person of height of 6'1" is "Medium Height" with Degree of Truth of 0.4 and "Tall" with a Degree of Truth of 0.6

Thus the transition is much smoother and more natural.

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Fuzziness vs Probability

Fuzziness ≠ Probability :

- **Fuzziness is deterministic uncertainty, but probability is non-deterministic.**
- **Probability describes whether an event occurs. Fuzziness describes the degree to which it occurs.**
- **Probabilistic uncertainty decreases with increasing number of occurences. Fuzziness does not.**

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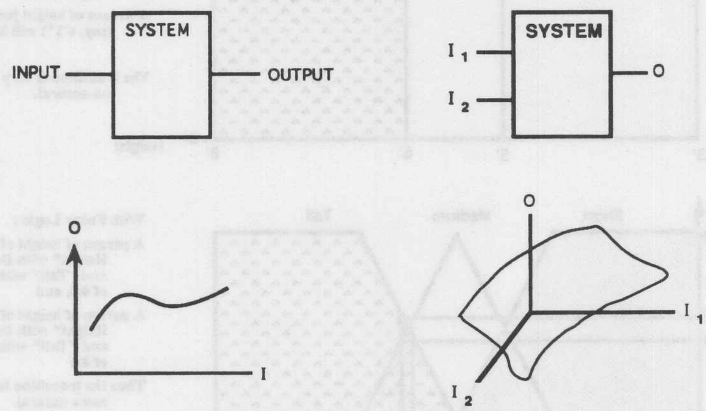
Control Surfaces



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Control System Approaches

Implementation	Advantages	Disadvantages
Lookup Table	• Simple	• Large memory required for complex surfaces
Mathematical Model	• Precise	• Model difficult or impossible to derive • Very Fast CPU's required to execute model in real time
Fuzzy Logic	• Simple • Intuitive • Robust to system Non-linearities	• Not suited for precise calculations

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Discrete Logic vs Fuzzy Logic

Two Valued Logic: True/False
- **Basis for Machine Operation**
- **Valued Items Must be Converted to This Form**

Multi-Valued Logic: True/False/Off
- **Useful for Internal Gating**
- **Never Became Popular as Computing Method**

Fuzzy Logic: Continuous [0,1]
- **Uses Linguistic Descriptions**
- **Categorizes Values into Set Membership**
- **Allows Focus of Attention to Important Details**
- **Reduces Computational Complexity**
- **Provides Platform for Expert Knowledge**
- **Complex Non-Linear Control Dynamics**
- **Relatively Simple to Implement in Software**
- **Works Well With Simple and Cheap Sensors**
- **Complements Neural Networks**

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Complexity vs Precision

Principle of Incompatibility :

"As the complexity of a system increases, our ability to make precise and yet significant statements about its behaviour diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics."

In other words, "Precision is Expensive.

To minimize cost, minimize precision.

To make a problem tractable, lower the precision"

- Lotfi Zadeh

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Fuzzy Sets

Fuzzy Set theory is a *generalization* of the Classical Set theory.

In *Classical* Set theory, an element is either *is* or *is not* a member of a set.

Law of Non-Contradiction : $A \cap \overline{A} = \emptyset$ (Null Set)

Law of Excluded Middle : $A \cup \overline{A} = X$ (Universe of Discourse)

In *Fuzzy* Set theory, an element can be a partial member of a set, with grade of membership a real number [0,1].

The above laws no longer apply since an element can now be a member of both a set and its complement.

For example, a half-filled glass is both 50% Full and 50% Empty.

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Fuzzy Set Operations

μ_{A1} (a) = Degree of Membership of variable (a) in Fuzzy Set A1

Intersection **(Logical AND)**

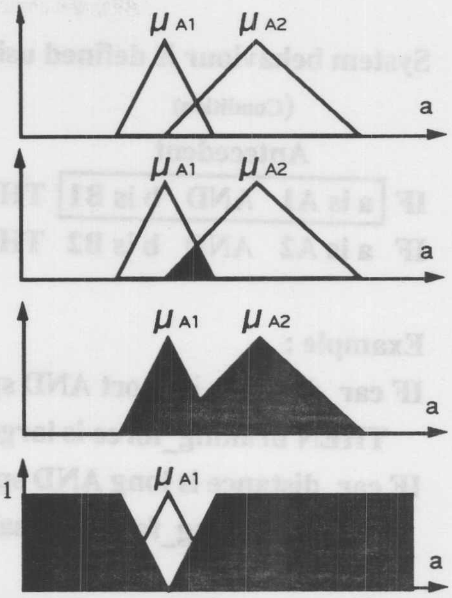
$\mu_{A1 \cap A2}(x) = \mathrm{MIN}[\mu_{A1}(x), \mu_{A2}(x)]$

Union **(Logical OR)**

$\mu_{A1 \cup A2}(x) = \mathrm{MAX}[\mu_{A1}(x), \mu_{A2}(x)]$

Complement **(Logical NOT)**

$\overline{\mu_{A1}}(x) = 1 - \mu_{A1}(x)$



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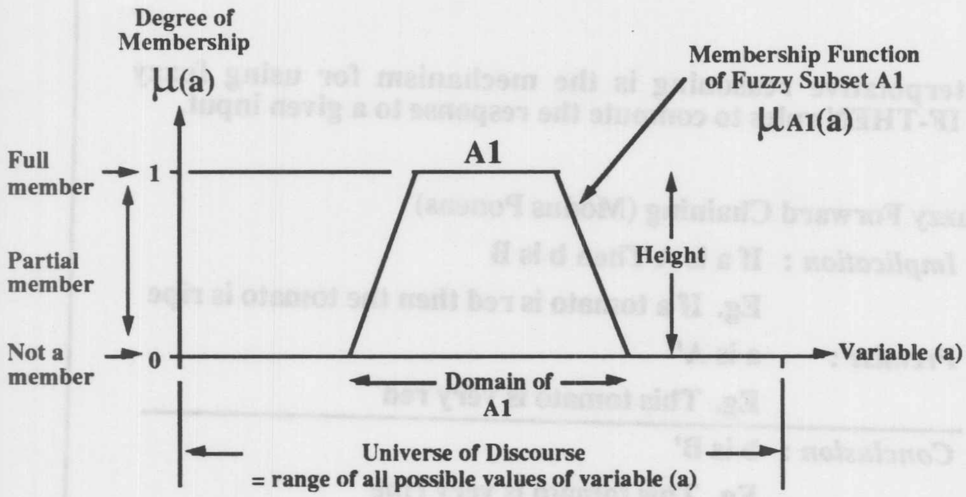
Fuzzy Set Terminology



Typically, Fuzzy Subsets are named linguistically as Labels, such as : Cold, Cool, Warm, Hot; Slow, Medium, fast; etc.

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Fuzzy Rules

System behaviour is defined using IF-THEN Rules :

	(Condition) Antecedent		(Action) Consequent
IF	$\boxed{\text{a is A1 AND b is B1}}$	THEN	$\boxed{\text{c is C1}}$
IF	a is A2 AND b is B2	THEN	c is C2

Example :

IF car_distance is short AND speed is medium
THEN braking_force is large

IF car_distance is long AND speed is slow
THEN braking_force is small

Fuzzy Interpolative Reasoning

Interpolative reasoning is the mechanism for using fuzzy IF-THEN rules to compute the response to a given input.

Fuzzy Forward Chaining (Modus Ponens)

***Implication* : If a is A Then b is B**

Eg. If a tomato is red then the tomato is ripe

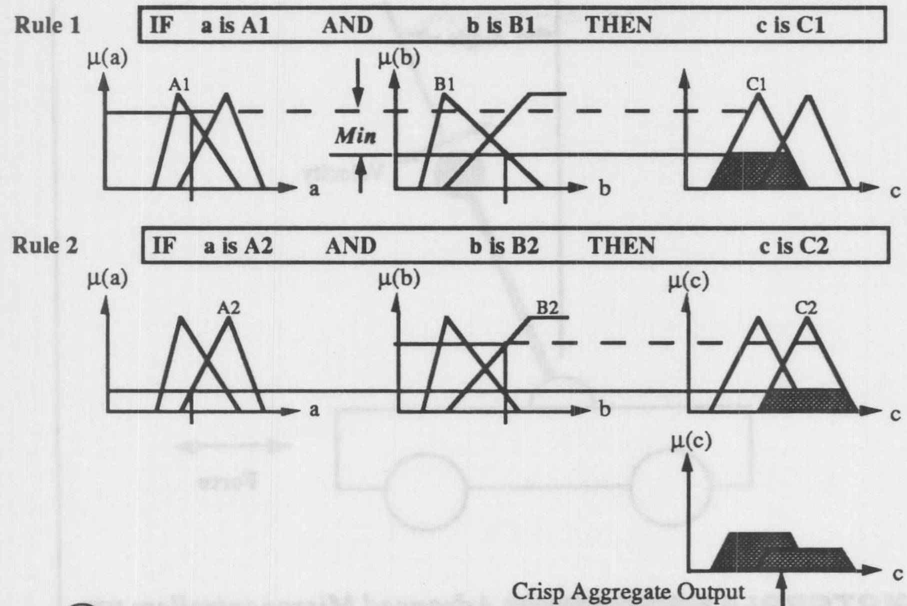
***Premise* : a is A'**

Eg. This tomato is very red

***Conclusion* : b is B'**

Eg. This tomato is very ripe

Fuzzy Inference



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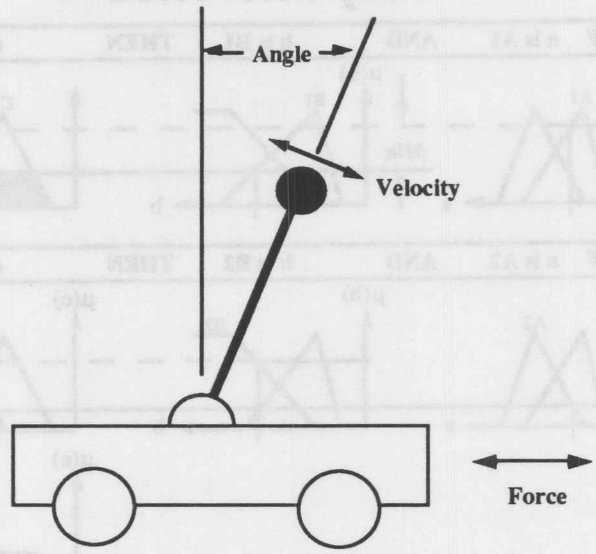
The Inverted Pendulum



The Pendulum Control System Conventional Approach

The conventional approach involves the derivation of a precise *mathematical model* describing the complete system.

The parameters may include

- **gravitational force constant**
- **weight of the pendulum,**
- **dimensions of each component ,**
- **electric motor dynamics**
- **friction**
- **airflow**

and invariably one has to assume a relatively *constant and simplified environment.*

The result is a high order differential equation that requires a high end microprocessor (such as the MC68040) in order to operate in real-time.

The Pendulum Control System
Fuzzy Logic Approach

The Fuzzy Logic approach parallels what humans do intuitively :

- **We sense the position of the pendulum *(Angle)* and its *Velocity* of motion**
- **Depending on the inputs, we apply different *Force* to the box car using intuitive rules such as:**

IF *Angle is Forward_Large and Velocity is Forward_Large*

THEN *Force is Forward_Large*

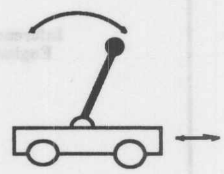
IF *Angle is Forward_Small and Velocity is Forward_small*

THEN *Force is Forward_Small*

IF *Angle is Zero and Velocity is Zero*

THEN *Force is Zero*

:



- **This simple rule based system can be implemented in real-time using the proper development tools on only a micro-controller like the 68HC11 !**

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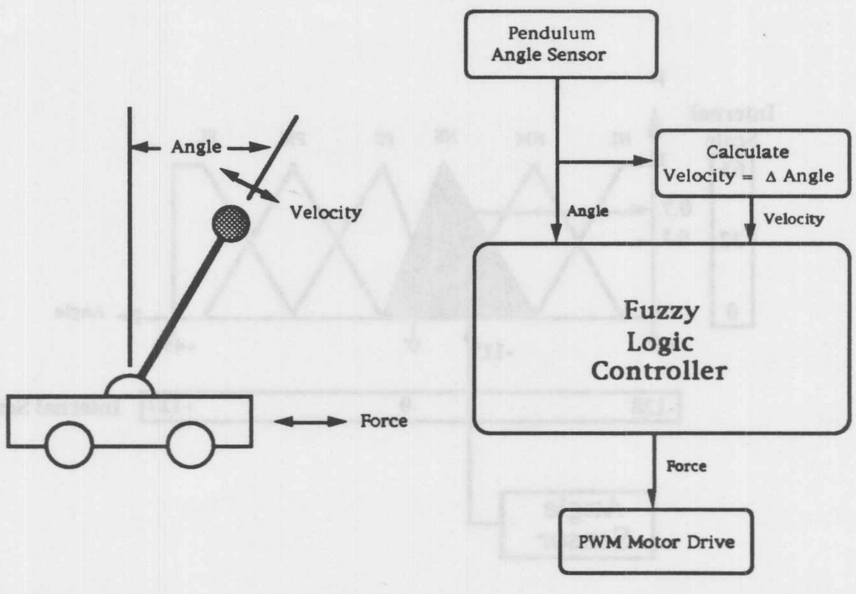
Inverted Pendulum Controller



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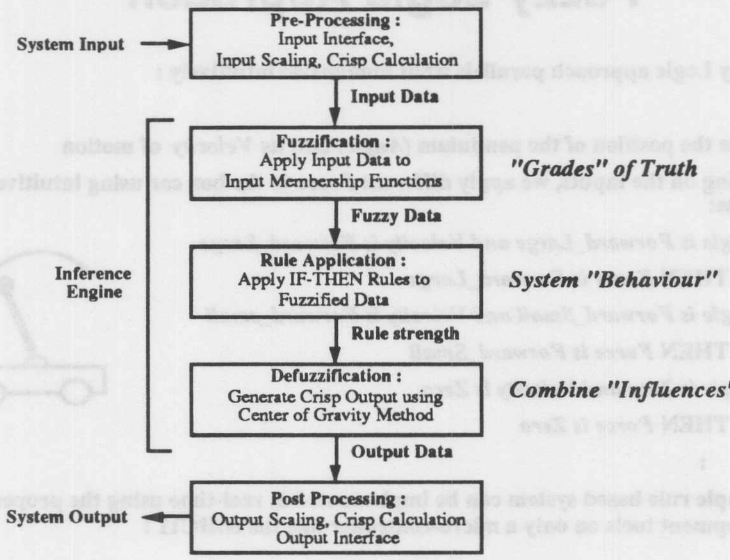
Fuzzy Logic Data Flow



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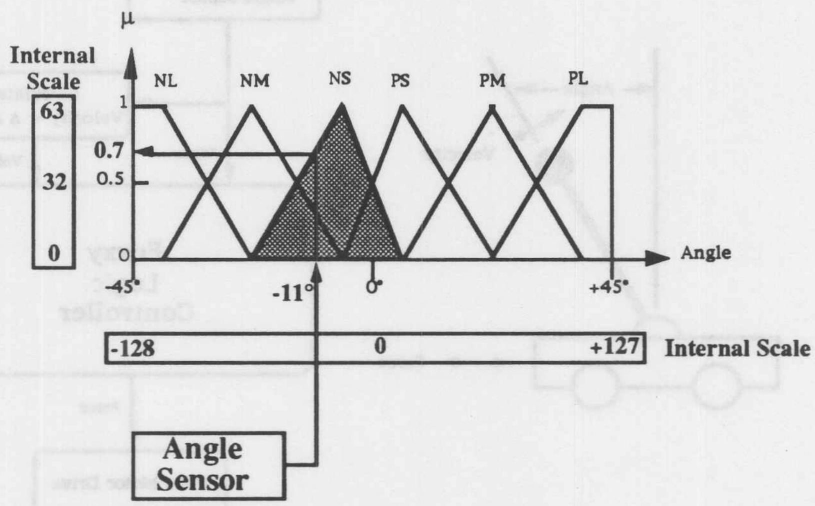
Input Membership Function



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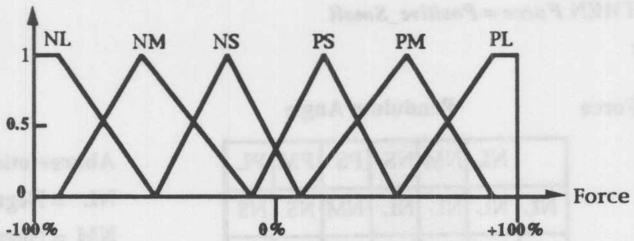
Output Membership Function



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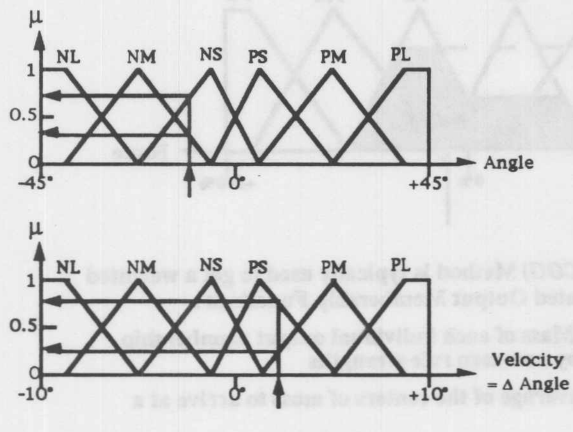
Fuzzification : Determine Membership

Input Membership Functions



Input Conditions :

Angle = -11°
Velocity = +2°

Fuzzified Input Data :

Label	*Angle*	*Velocity*
Neg_Large	0	0
Neg_Medium	0.35	0
Neg_Small	0.7	0
Pos_Small	0	0.75
Pos_Medium	0	0.25
Pos_Large	0	0

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Pendulum Rules

IF *Angle = Negative_Medium* AND *Velocity = Positive_Small*
THEN *Force = Negative_Small*
IF *Angle = Negative_Medium* AND *Velocity = Positive_Medium*
THEN *Force = Positive_Small*
:

Force — Pendulum Angle (columns) / Pendulum Velocity (rows)

	NL	NM	NS	PS	PM	PL
NL	NL	NL	NL	NM	NS	NS
NM	NL	NL	NM	NS	NS	PS
NS	NL	NM	NS	NS	PS	PM
PS	NM	NS	PS	PS	PM	PL
PM	NS	PS	PS	PM	PL	PL
PL	PS	PS	PM	PL	PL	PL

Abbreviations :
NL = Negative_Large
NM = Negative_Medium
NS = Negative_Small
PS = Positive_Small
PM = Positive_Medium
PL = Positive_Large

Angle

NS	PS
NS	PS

Δ Ang = Vel

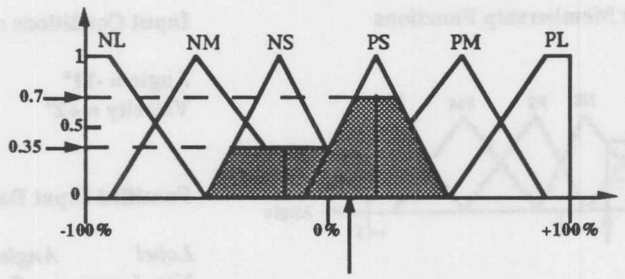
NS = .02

m(.35,.7) = .35	m(.7,.7) = .7
m(.25,.35) = .25	m(.7,.25) = .25

PS = max (.7, .25, .25) = .7

MIN MAX METHOD = and or

Defuzzification : Calculate Expected Crisp Output

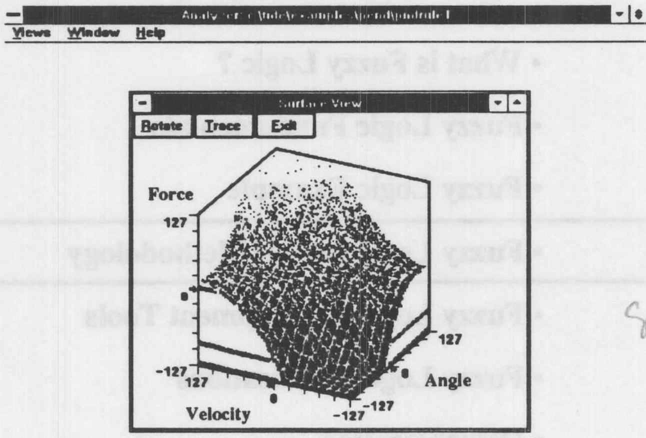


The *Center of Gravity (COG)* Method is typically used to get a weighted average of the activated Output Membership Functions :

(1) Calculate Center of Mass of each individual output membership function truncated by non-zero rule strengths

(2) Calculate weighted average of the centers of mass to arrive at a crisp output value

Pendulum Control Surface



see brochure

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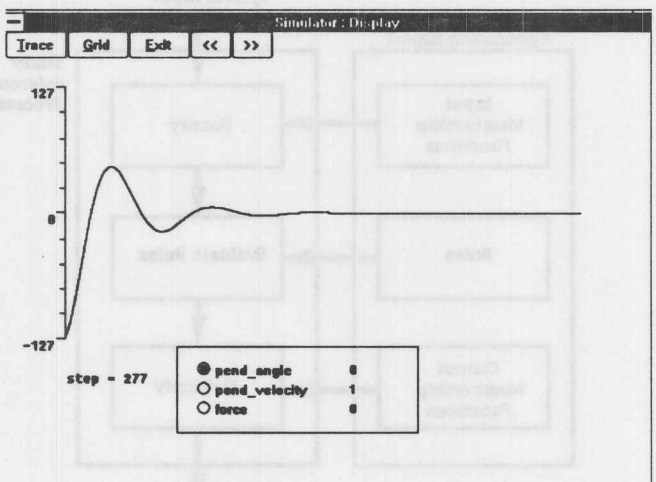
Pendulum Dynamic Response



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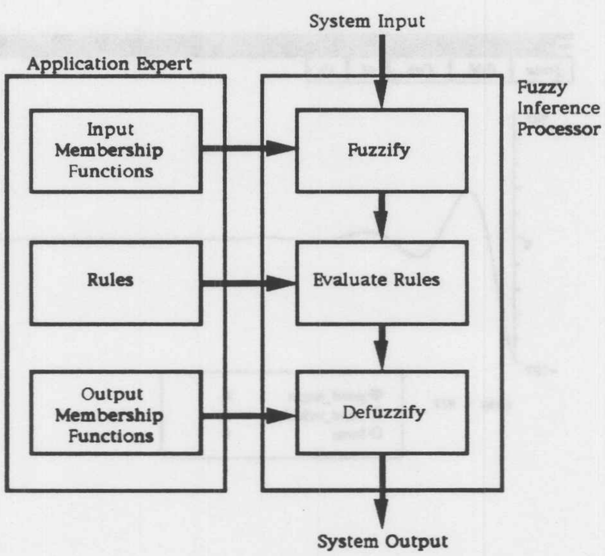
Fuzzy System Block Diagram



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Fuzzy Logic Design Parameters

- **Number of Inputs and Outputs**
- **Input and Output Quantization Accuracy :**
  - **- Range and Resolution of Universe of Discourse**
- **Number of Fuzzy Sets associated for every Input and Output :**
  - **- Number of Linguistic Labels**
- **Shape and Location of each Fuzzy Set :**
  - **- Bell, Trapezoidal, Triangular or Singleton shapes**
  - **- Spacing and Overlap of Fuzzy Sets**
- **Rules**
- **Defuzzification Method**
- **Implementation Scheme**

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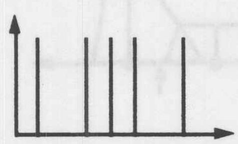
Membership Function Shapes

MF Shape	*Features*
Bell (Normal) Curve	**• Smoother transitions** **• More natural** **• Computationally Expensive** **• Storage Intensive** **• Long tails may cause noise**
Trapezoidal or Triangular	**• Easy Fuzzification** **• Most commonly used in practice** **• Minimal degradation in performance**
Singleton	**• Simplifies Defuzzification** **• Rougher transitions** **• Used only in output MF**



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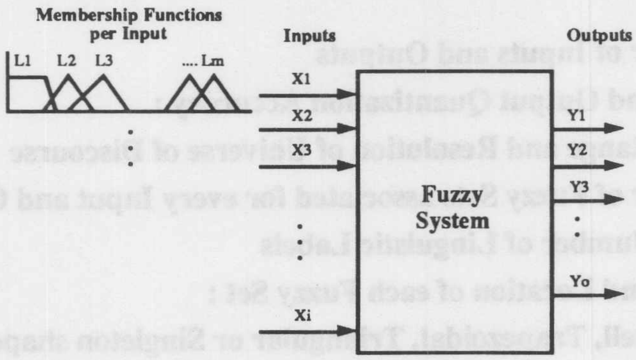
Fuzzy Logic Rules



Total Number of Possible Rules :

= (# Outputs) x [# Membership Functions per Input] (# Inputs)**

AI ~ maximum rule set

Typically, the number of rules actually used is much smaller than the maximum.

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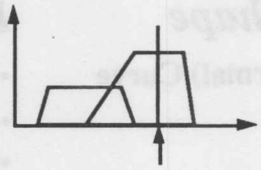
Defuzzification Methods

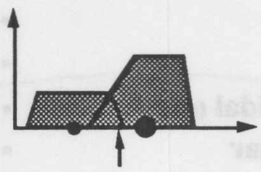
***Mean of Maxima* Method**

- **Crisp Output = Mid-Point of Maximum MF**



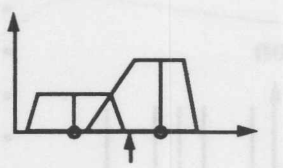
***Center of Gravity* Method**

- **Crisp Output = Weighted Average of Centers of MF Mass**



***Height* Method**

- **Crisp Output = Weighted Average of (MF Height * Output value at Mid-point of MF top)**



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Use of Singletons in Output Membership Functions

- Use of Singletons simplifies Center of Gravity Defuzzification by eliminating center of mass calculations
- Comparison with trapezoidal or triangular membership functions :
  - *Position* of center of mass at varying output rule strengths is similar to any *symmetrical* membership functions
  - However, the *weight* at each center of mass is underbiased when compared to membership functions with non-zero area
- Singletons are attractive for microcontroller implementations

Implementation Scheme

Memory Table Lookup Method

- Build lookup table that maps any combination of inputs to outputs
- Fast execution time
- Memory intensive

Active Inference Method

- Perform fuzzy inference during run-time
- Smaller memory requirement
- Easier in-system tuning
- Required for adaptive fuzzy systems
- Practical for complex fuzzy inference units

Fuzzy Logic Development Cycle

(1) Start with a full specification of the system.
Not a mathematical model, just how the system should work !
(2) Define Input and Output Ranges.
(3) Define Membership Functions for each Input and Output.
(4) Construct a rule base of IF/THEN rules that describe how the system works.
Take advantage of experience of human experts !
(5) Simulate system and tune design by modifying membership functions. Rule base can also be incrementally developed.
This is where a graphical development environment really helps !
(6) Compile Membership Functions and Rules for target Microcontroller.
(7) Add Preprocessing and Postprocessing code to complete application.
Both Conventional and Fuzzy approaches will coexist in an application !

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Fuzzy Logic Seminar

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Motorola Fuzzy Logic Tools

For Entry Level Development and Evaluation

(1) Knowledge Base Generator (KBG)
- **Membership Function Editor**
- **Rules Editor**
- **Simple Control Contour (2-D) Display**
- **Assembly Data Structure Generator**

(2) Fuzzy Inference Run-Time Kernels
- **68HC05**
- **68HC11**

Available to customers at no charge.

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Motorola KBG and Kernels : Features

- **1- 4 Inputs with 8 trapezoidal MF's each**
- **1-2 Outputs with 8 singleton MF's each**
- **Each trapezoidal Membership Function is stored as two (point, slope) pairs as 4 bytes**
- **Each Antecedent or Consequent is stored as 1 byte**
- **Unlimited number of Antecedents and Consequents per rule**
- **8-bit data implementation**

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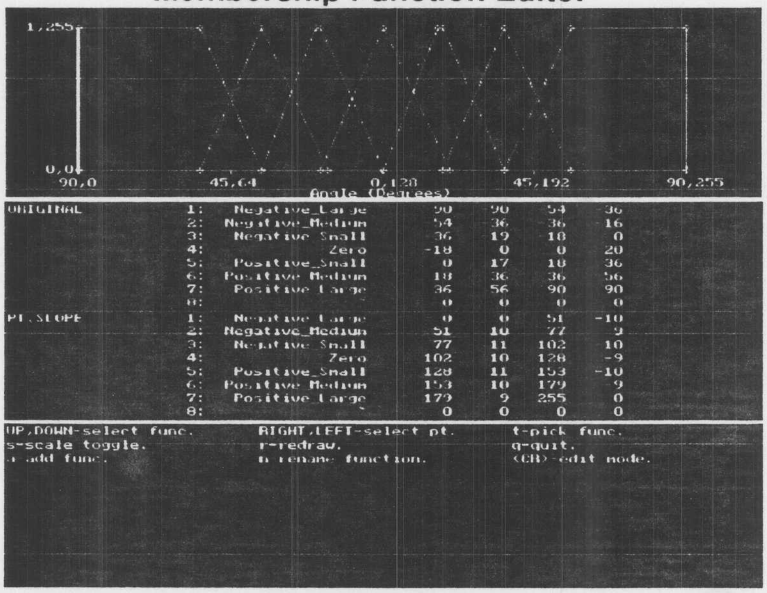
KBG Sample Display

Membership Function Editor



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Aptronix

Fuzzy Inference Development Environment

FIDE ("Fee-Day")

- **A Complete, Integrated Environment :**
  - **Source Code *Text Editor***
  - **Membership Function *Graphical Editor***
  - ***Debugger***
    - **Static Input to Output *Tracer***
    - **3-D Graphical Transfer Function *Analyzer***
    - **Dynamic Response *Simulator***
  - **System *Composer***
    - **Graphical System Level Simulator**
    - **Linkage to external user written modules**
  - **Real Time Code Generator for HC05 & HC11 (HC16, 68300 and DSP56001 versions soon)**
- **MS Windows 3.0+ based**

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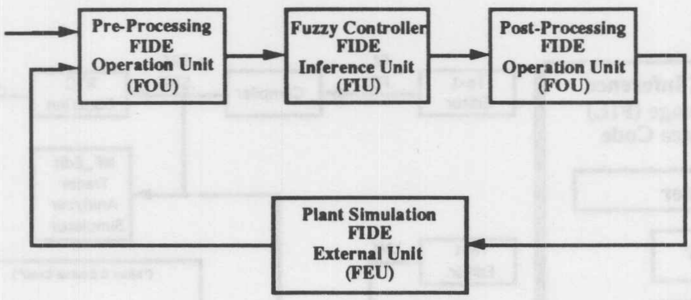
System Simulation with FIDE



Full System Simulation with

- **Graphical flow graph editor**
- **Multiple fuzzy and system units**
- **Dataflow tracing**
- **Automatic generation of runtime program**

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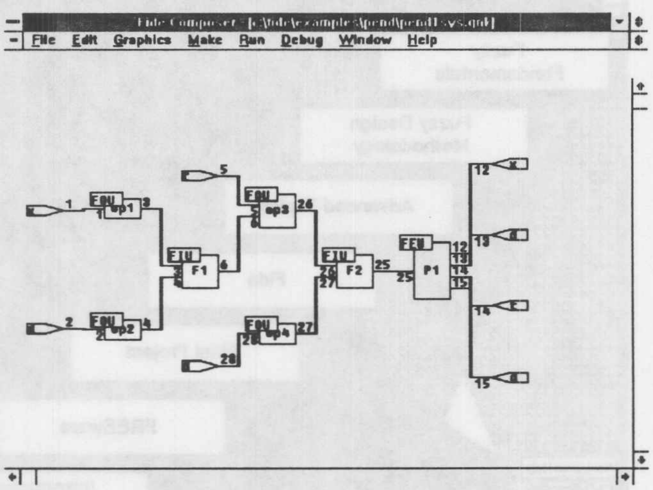
FIDE System Composer Example



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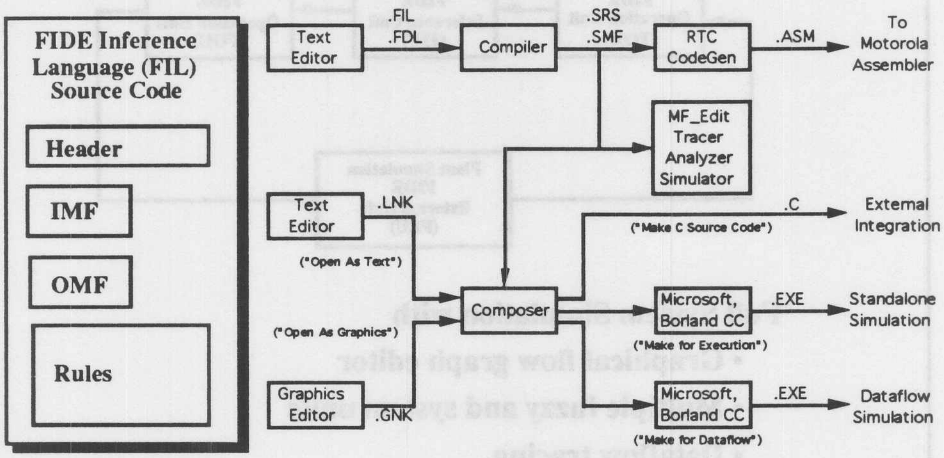
FIDE Structure



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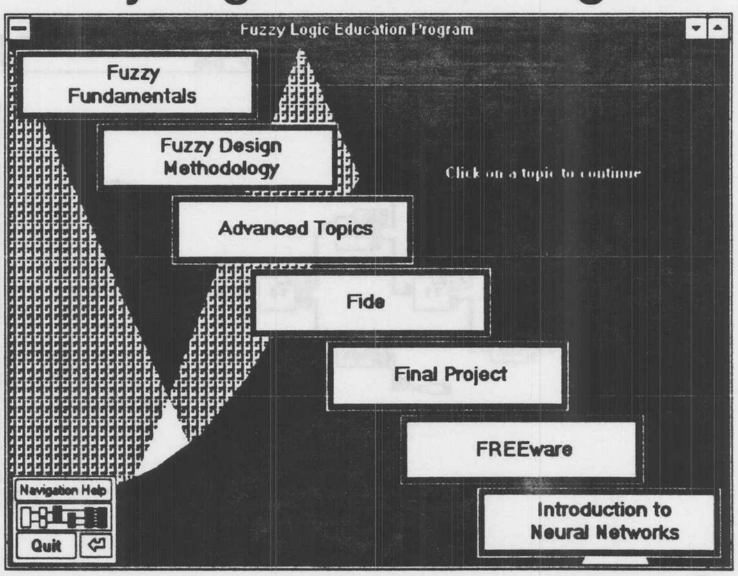
Learn More with Motorola's Fuzzy Logic Tutorial Program



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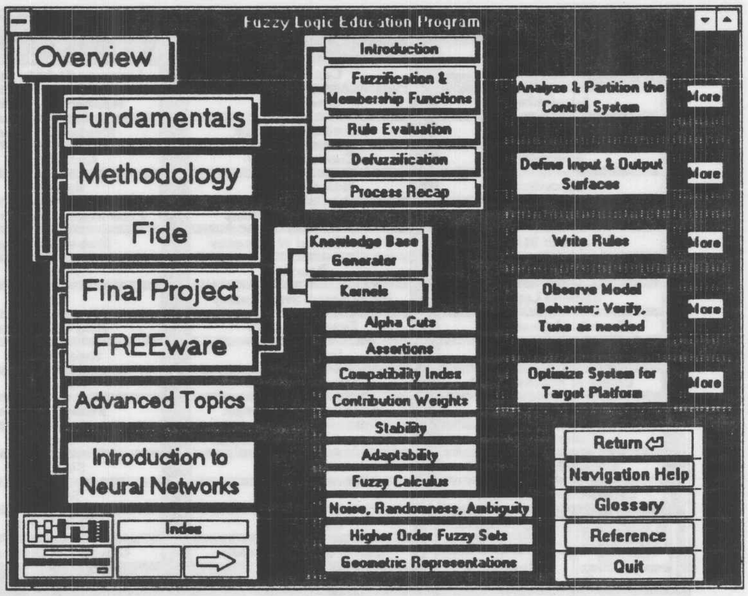
Fuzzy Logic Tutorial - Overview



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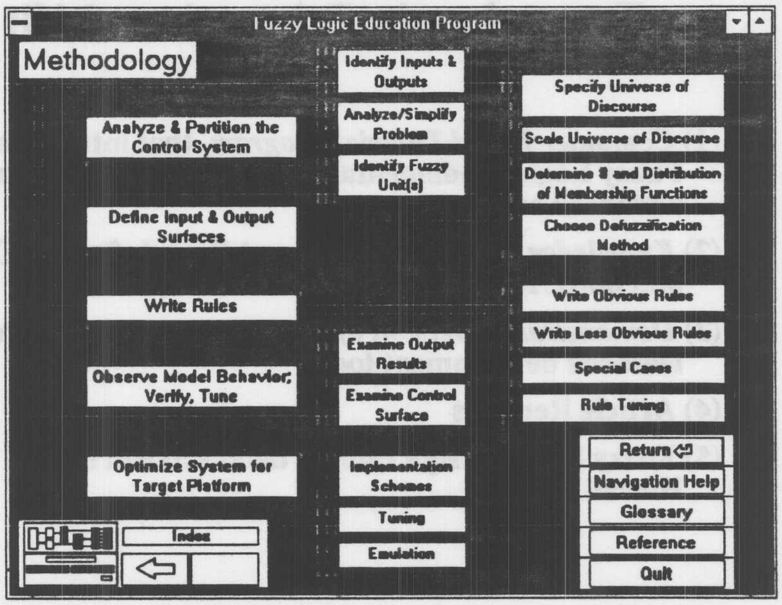
Fuzzy Logic Tutorial - Overview (cont'd)



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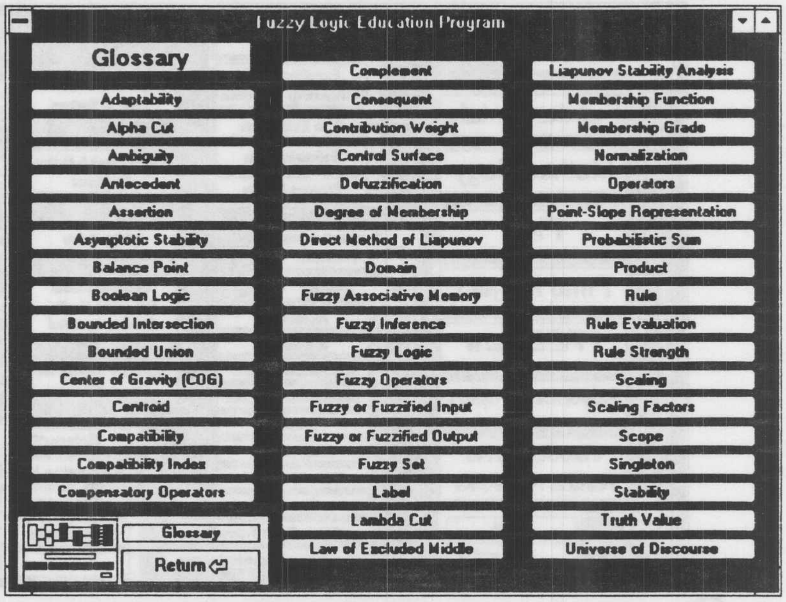
Fuzzy Logic Tutorial - Glossary



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Motorola Fuzzy Logic Educational Kit

(1) *Computer Based Tutorial Program* that introduces Fuzzy Logic fundamentals, design methodology and advanced concepts

(2) *Knowledge Base Generator* and *Kernels* for 68HC05 and 68HC11

(3) *Demonstration version of FIDE* to test drive the full featured development tool

(4) Article Reprints

(5) Fuzzy Logic *Design Contest* details to win trip to Hawaii

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Motorola / Aptronix Fuzzy Logic Tools

Part Number	Price	Description
FLEDKT00	$295	Fuzzy Logic Educational Kit Only
	$195	(Special offer, before August 31, 1992)
FLEDKT05*	$600	Fuzzy Logic Educational Kit bundled with HC05EVM
FLEDKT11*	$600	Fuzzy Logic Educational Kit bundled with HC11EVM
M68HXBFIDS	$1495	Aptronix Fuzzy Inference Development Environment (FIDE) Software

Each Educational Kit includes :
(1) Computer-Based Tutorial Program, (2) Demo Version of FIDE, (3) Freeware Fuzzy Tools, (4) Article Reprints and (5) Hawaii Contest Details.

* Note : Only limited quantities available

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Fuzzy Logic Seminar

- What is Fuzzy Logic ?
- Fuzzy Logic Fundamentals
- Fuzzy Logic Example
- Fuzzy Logic Design Methodology
- Fuzzy Logic Development Tools
- Fuzzy Logic Applications
- Demonstration
- Summary and Doorprize Draw

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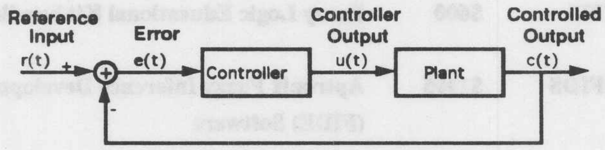
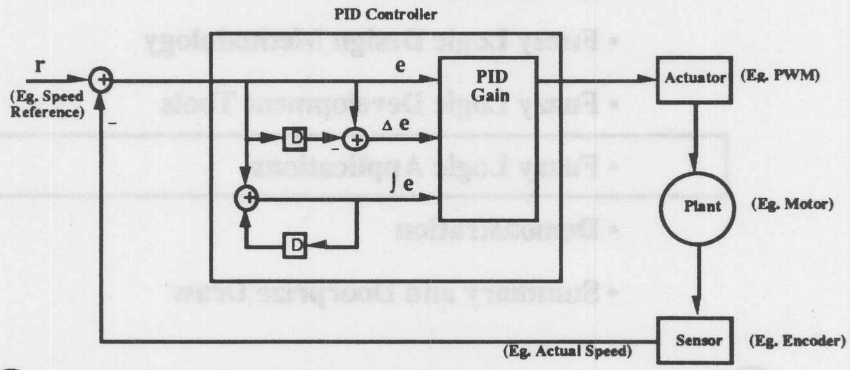
Closed Loop Control Application



PID Controllers

$$\frac{U(s)}{E(s)} = K_p + \frac{K_i}{s} + K_d\, s$$

K_p = Proportional Gain => ~~Increases~~ reduces Rise Time
K_d = Differential Gain => Reduces Overshoot
K_i = Integral Gain => Reduces Steady State Error but slows rise time



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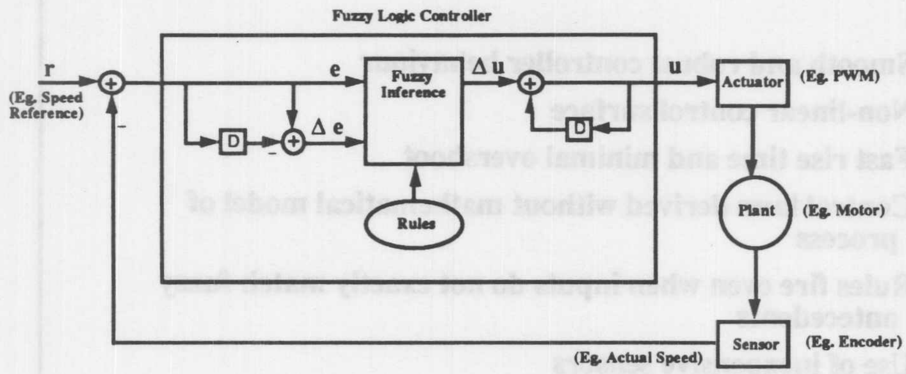
Fuzzy Logic Controller



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Sample Fuzzy Servo Controller Rules

IF Error is pos_large AND ΔError is neg_small THEN ΔPWM is zero
IF Error is pos_large AND ΔError is zero THEN ΔPWM is pos_large
IF Error is pos_large AND ΔError is pos_small THEN ΔPWM is pos_large

IF Error is neg_large AND ΔError is neg_small THEN ΔPWM is zero
IF Error is neg_large AND ΔError is zero THEN ΔPWM is neg_large
IF Error is neg_large AND ΔError is pos_small THEN ΔPWM is neg_large

IF Error is pos_small AND ΔError is neg_small THEN ΔPWM is neg_small
IF Error is pos_small AND ΔError is zero THEN ΔPWM is pos_small
IF Error is pos_small AND ΔError is pos_small THEN ΔPWM is pos_small

IF Error is neg_small AND ΔError is neg_small THEN ΔPWM is pos_small
IF Error is neg_small AND ΔError is zero THEN ΔPWM is neg_small
IF Error is neg_small AND ΔError is pos_small THEN ΔPWM is neg_small

IF Error is zero AND ΔError is neg_small THEN ΔPWM is zero
IF Error is zero AND ΔError is zero THEN ΔPWM is zero
IF Error is zero AND ΔError is pos_small THEN ΔPWM is zero

PID approach there will be a Fuzzy logic PID loop.

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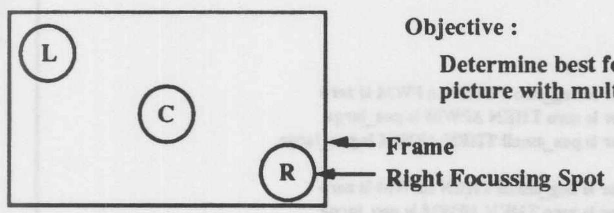
Fuzzy Logic Controller Properties

- Smooth and robust controller behaviour
- Non-linear control surface
- Fast rise time and minimal overshoot
- Control laws derived without mathematical model of process
- Rules fire even when inputs do not exactly match fuzzy antecedents
- Use of inexpensive sensors

Camera Autofocus Application (Canon)



Objective :

Determine best focus and lighting for picture with multiple objects

DL, DC, DR = **Distance of object at Left, Center and Right spots respectively**

PL, PC, PR = **Plausibility that object of interest is at Left, Center or Right resp.**

IF *DL is Near* THEN *PL is High*

IF *DC is Near* THEN *PC is High*

IF *DR is Near* THEN *PR is High*

IF *DL is Far* AND *DC is Medium* AND *DR is Near* THEN *PC is High*

IF *DL is Near* AND *DC is Medium* AND *DR is Far* THEN *PC is High*

Fuzzy Logic decision is correct 96.5% compared to 76.3% with standard method

Cargo Transport Application

The Problem

A large container shipping company needs to ship cargo from any location in the world to any other, using the least expensive and most expedient ship.

The Exact Solution

A team of mathematicians derived the mathematically exact solution. The numerical algorithm takes 35 hours on a Cray mainframe in order to solve the problem. This technique finds the exact solution to the problem.

This solution, though exact, was clearly impractical to implement since it takes 1.5 days per run !

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The Fuzzy Cargo Transport Solution

The fuzzy approach uses 175 rules with 10 input functions and 3 output functions.

This solution runs on an IBM mainframe in several minutes. This is an appropriate timeframe for the problem. Although this approach does not find the absolute minimum solution of the problem, it was able to save the user several million dollars a month.

The Result

Although inexact, the fuzzy solution was more practical and efficient than the numerical approach. It achieved the desired result which was better efficiency in cargo shipments.

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Other Applications

Product	Role of Fuzzy Logic
Air Conditioner	Determines optimum constant operating level to prevent power consuming on/off cycling
Auto Transmission	Senses driving style and engine load to select best gear ratio
Elevator Control	Evaluates passsenger traffic to reduce waiting time
Golf Diagnostics	Selects best golf club for individual's physique and swing
Palmtop Computer	Interprets handwritten input for data entry
Stock Trading	Manages Stock Portfolio
Television	Adjusts screen brightness, color and contrast
Train Control	Controls motor and brakes for smooth acceleration, deceleration and braking for comfort, safety and efficiency
Vacuum Cleaner	Senses floor condition and dust quantity to adjust vacuum motor power
Washing Machine	Senses quality and quantity of dirt, load size and fabric type to automatically adjust wash cycle
Water Heater	Adjusts heating element to correspond to temperature and amount of water being used

(Source : Kevin Self, IEEE Spectrum)

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Fuzzy Logic Application Types

Type	Problem Nature	Objectives	Examples
Tracking	• Noisy, Time-variant Systems • Non-Linear Systems	• Faster Response • Reduced Overshoot • Robustness	• Temperature, Tension, & Position Control • Chemical Plant
Tuning	• Conflicting Constraints	• Higher Precision • Higher Efficiency	• Gain Tuning, • Crane Control
Human Factors	• Intuitive Feel • Difficult to Automate	• Material Efficiency • Higher Productivty	• Cruise Control • Diagnostic Systems • Steering Control
Interpolation	• Multi-inputs • Multi-level Processing	• Higher Precision • Higher Efficiency • Lower Maintenance	• Air Conditioner • Washing Machine • Gas Flow Regulator
Classification	• Complex Pattern Recognition	• Higher Accuracy • Robustness	• Hand-writing Recognition

(Source :Dr. Satoru Isaka)

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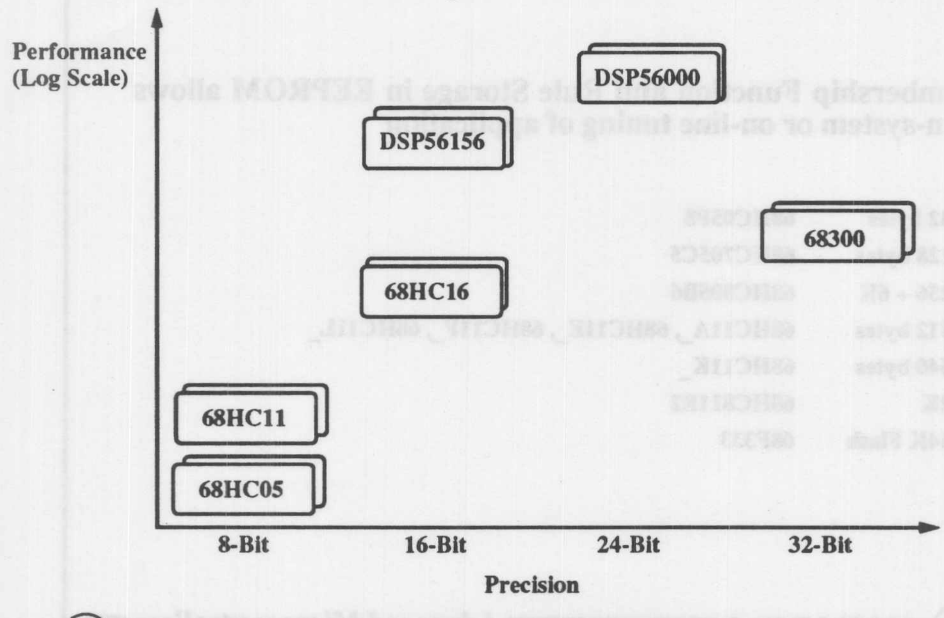
Fuzzy Logic Application Requirements

- Integrated or Single-chip System Implementation
- Sensor and Actuator Interfaces
- Knowledge Base Storage
- Wide Cost/Performance MCU Portfolio

Motorola "Fuzzy" Microcontrollers



Sensor Input and Actuator Output

Smart Applications using Fuzzy Logic utilize more sensors and actuators for more automatic operations

- A/D Converter
  - On Chip A/D
    - 68HC05B_, 68HC05P9, 68HC05T10
    - 68HC11A_, E_, F_, K_, L_,
    - 68HC16Z1, Y1
  - Serial (SPI Compatible) A/D
    - MC145050/51/53 (10-bit, 5-11 Channels)
- D/A Converter
  - Timer Based PWM
    - All 68HC05, 68HC11, 68300
  - Hardware PWM
    - 68HC05B_, 68HC05H_, 68HC05T_,
    - 68HC11K_,

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Knowledge Base Storage

Membership Function and Rule Storage in EEPROM allows in-system or on-line tuning of application

32 bytes	68HC05P8
128 bytes	68HC705C5
256 + 6K	68HC805B6
512 bytes	68HC11A_, 68HC11E_, 68HC11F_, 68HC11L_
640 bytes	68HC11K_
2K	68HC811E2
64K Flash	68F333

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Fuzzy Logic Benefits

- More *Product Features* without significant cost increase
- Lower *Cost* implementation (due to reduction in CPU horsepower)
- Faster *Time-to-Market* for new products
- Easier *Modifications* for feature enhancement
- Better *Performance* than conventional methods
- Handles system *Non-Linearity* transparently
- Incorporate knowledge of application *Expert* in design
- Handles problems too difficult to formulate with conventional methods

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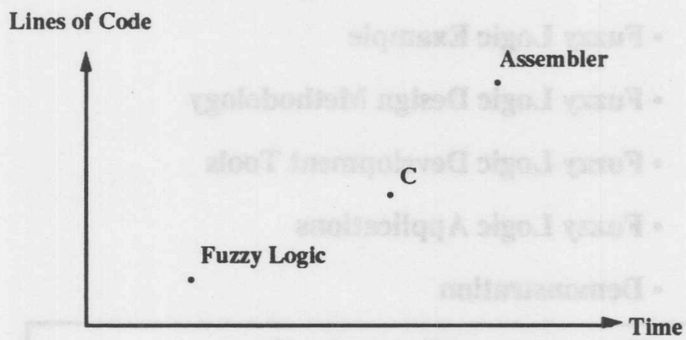
Time to Market Advantage



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Paradigm Shifts

A *Paradigm* is a specific way we look at the world.

"It is *a set of rules and regulations* that (1) defines boundaries and (2) tells us what to do to be successful (in solving problems) within those boundaries."*

Some examples of Paradigm Shifts :

Horse Carriages ---> *Automobiles*

Vacuum Tubes ---> *Transistors*

Mechanical Watches ---> *Digital Watches*

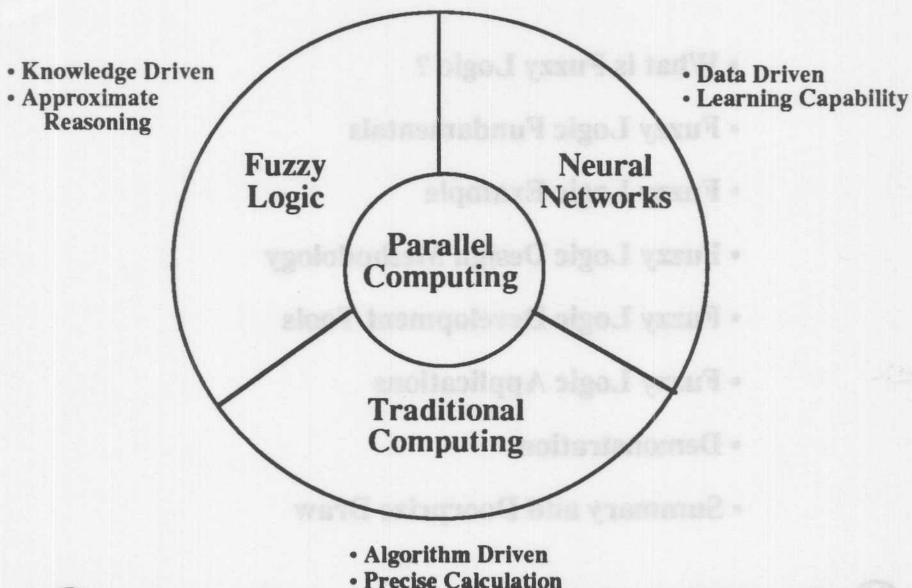
Binary Logic ---> *Fuzzy Logic*

There are tremendous advantages to be gained as an early adopter of a new paradigm and grave consequences if one chooses to ignore it.

Remember what happened to the Swiss dominance in the watch market ?

* Quotes from Joel Arthur Barker's "Discovering the Future , the business of paradigms", ILI Press, 1990

The Future of Computing



Fuzzy Logic References

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- James Sibigtroth, "Creating Fuzzy Micros", Embedded Systems Programming, December 1991
- James Sibigtroth, "Applying Fuzzy Logic to Embedded Systems", AI Expert, April 1992
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- Daniel Schwartz & George Klir, "Fuzzy Logic flowers in Japan", IEEE Spectrum, July 1992, p32-35

Papers

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- Chuen Chien Lee, "Fuzzy Logic in Control Systems : Fuzzy Logic Controller", IEEE Trans. on Systems, Man & Cybernetics, Vol20, #2, March/April 1990, pp404-433
- Proceedings of IEEE International Conference on Fuzzy Systems, San Diego, March 8-12, 1992, IEEE Catalog Number 92CH3073-4 (1-800-678-IEEE)

Textbooks

- H.J. Zimmerman, "Fuzzy Set Theory - and its Applications", 2nd Ed, Kluwer Academic Publishers, 1991
- Bart Kosko, "Neural Networks and Fuzzy Systems", Prentice Hall, 1992

Video

- "Fuzzy Logic : Applications and Perspectives", IEEE Videoconferences, April 25, 1991

MOTOROLA Semiconductor Products Sector — *Advanced Microcontrollers*

Fuzzy Logic Seminar

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MOTOROLA Semiconductor Products Sector — *Advanced Microcontrollers*

M68HC05 Microcontrollers

Selector Guide
2Q92

MOTOROLA
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Advanced Microcontrollers

MICROCONTROLLERS

Motorola Part Number	ROM	RAM	EEPROM	Timer	Serial	A/D	I/O	Bus Speed, MHz	Package†	EPROM or EEPROM Version	Comments
M68HC05 (HCMOS) All products available now except where noted in Comments.											
MC68HC05B4	4K	176	0	16-Bit–2 IC, 2 OC, WDOG	SCI	Yes	32	0-2.1	56-B 52-FN	705B5 805B6	2 PWMs
MC68HC05B6	6K	176	256	16-Bit–2 IC, 2 OC, WDOG	SCI	Yes	32	0-2.1	56-B 52-FN	705B5 805B6	2 PWMs
MC68HC05B8	8K	176	256	16-Bit–2 IC, 2 OC, WDOG	SCI	Yes	32	0-2.1	56-B 52-FN	N/A	2 PWMs
MC68HC05C4	4K	176	0	16-Bit–1 IC, 1 OC	SPI, SCI	No	31	0-2.1	40-P 44-FN 44-FB	705C8 805C4	Low Voltage & High Speed Versions Available
MC68HC05C5	5K	176	128	16-Bit–1 IC, 1 OC, WDOG	SIOP	No	32	0-2.1	40-P 44-FN	705C5	10 mA Sink Port, LVPI
MC68HC05C8	8K	176	0	16-Bit–1 IC, 1 OC	SPI, SCI	No	31	0-4.0	40-P 44-FN 44-FB	705C8	Low Voltage & High Speed Versions Available
MC68HC05C9	16K	352	0	16-Bit–1 IC, 1 OC, WDOG	SPI, SCI	No	31	0-2.1	40-P 44-FB 44-FN	705C9	Expanded Port D
MC68HC05D9	16K	352	0	16-Bit–1 IC, 1 OC	SCI	No	31	0-2.1	40-P 44-FN	705D9	5 PWMs, 25 mA Sink Port
MC68HC05D24	24K	352	0	16-Bit–1 IC, 1 OC, WDOG	SCI	No	31	0-2.1	40-P 44-FN	N/A	5 PWMs, 24 mA Sink Port
MC68HC05E0	0	480	0	2 Periodic Timers, WDOG	SPI or I^2C	No	36	0-4.0	68-FN	N/A	External Address
MC68HC05E1	4K	368	0	15 stage multi-function, RTC, RTI, WDOG	—	No	20	0-4.0	28-P 28-DW	705E1	Internal PLL Clock Synthesizer
XC68HC05F6	4K	320	0	16-Bit–1 IC, 1 OC	SPI	No	28	0-2.1	42-B	N/A	DTMF
XC68HC05G8	8K	172	0	15 stage multi-functional, RTC, WDOG	Dual SCI	Yes	40	0-2.1	160-FT	N/A	Power Management, PLL, Keyboard Control
XC68HC05H2	2K	128	0	15 stage multi-function, RTI, WDOG	SIOP	No	16	0-2.1	40-P, 42-B 44-FB	705H2	LDMOS, 2 PWMs Production 1Q93
MC68HC05J1	1K	64	0	15 stage multi-function, RTI, WDOG	—	No	14	0-2.1	20-P 20-DW	705J2	Low Cost
XC68HC05L5	8K	256	0	16-Bit–1 IC, 1 OC 8-Bit–1 IC, 1 OC	SIOP	No	39	0-2.1	80-FU	N/A	156-Segment LCD, External Address
XC68HC05L6	6K	176	0	16-Bit–1 IC, 1 OC	SPI	No	24	0-2.1	68-FN	N/A	96-Segment LCD
MC68HC05L7	6K	176	0	16-Bit–1 IC, 1 OC, RTC	SCI	No	27	0-2.1	128-FT Die	N/A	960 Segment LCD, External Address
MC68HC05L9	6K	176	0	16-Bit–1 IC, 1 OC, RTC	SCI	No	27	0-2.1	128-FT Die	N/A	640 Segment LCD, External Address
MC68HC05L10	13K	352	0	16-Bit–1 IC, 1 OC	SPI, SCI	No	28	0-3.6	128-FT Die	N/A	LCD Driver, MMU, External Address
XC68HC05M4	4K	128	0	8-Bit; 16-Bit–1 IC, 1 OC, WDOG	—	Yes	32	0-2.1	52-FN	N/A	24 Lines (3 Ports) VFD on Chip
MC68HC05P1	2K	128	0	16-Bit–1 IC, 1 OC	—	No	21	0-2.1	28-P 28-DW	705P9	
XC68HC05P3	3K	128	128	16-Bit–1 IC, 1 OC WDOG	—	No	22	0-2.1	28-P 28-DW	N/A	Keyboard Interrupt
MC68HC05P4	4K	176	—	16-Bit–1 IC, 1 OC, WDOG	SIOP	—	21	0-2.1	28-P 28-DW	705P6	
MC68HC05P7	2K	128	0	16-Bit–1 IC, 1 OC, WDOG	SIOP	No	21	0-2.1	28-P 28-DW	705P9	
XC68HC05P8	2K	112	32	15 stage multi-function, RTI, WDOG	—	Yes	20	0-2.1	28-P 28-DW	505P8	LVPI Option on EEPROM
XC68HC05P9	2K	128	—	16-Bit–1 IC, 1 OC, WDOG	SIOP	Yes	21	0-2.1	28-P 28-DW	705P9	Low cost
MC68HC05SC11	6K	128	0	—	—	No	5	0-2.1	Die	N/A	8K EPROM, Security
MC68HC05SC21	6K	128	3K	—	—	No	5	0-2.1	Die	N/A	Security
MC68HC05SC24	3K	128	1K	—	—	No	5	0-2.1	Die	N/A	Security
MC68HC05T1	8K	320	—	16-Bit–1 IC, 1 OC, WDOG	SIOP	Yes	30	0-2.1	40-P	705T3	On-Screen Display, 9 PWMs
XC68HC05T2	15K	320	0	16-Bit–1 IC, 1 OC, WDOG	SIOP	Yes	30	0-2.1	40-P	705T3	On-Screen Display, 9 PWMs

MICROCONTROLLERS (Continued)

Motorola Part Number	ROM	RAM	EEPROM	Timer	Serial	A/D	I/O	Bus Speed, MHz	Package†	EPROM or EEPROM Version	Comments
M68HC05 (HCMOS) (Continued) All products available now except where noted in Comments.											
XC68HC05T4	5K	96	0	16-Bit–1 IC, 1 OC, WDOG	—	Yes	16	0-2.1	42-B	705T4	On-Screen Display, 6 PWMs
XC68HC05T7	8K	320	0	16-Bit–1 IC, 1 OC, RTC	I^2C	Yes	28	0-2.1	56-B	705T7	On-Screen Display, 9 PWMs
M6804 (HMOS) All products available now except where noted in Comments.											
MC6804J1	504	32	0	8-Bit	—	No	12	83-229 kHz	20-P	N/A	
MC6804J2	1000	32	0	8-Bit	—	No	12	83-229 kHz	20-P	N/A	
MC6804P2	1024	32	0	8-Bit	—	No	20	83-229 kHz	28-P	704P2	
M6805 (HMOS) All products available now except where noted in Comments.											
MC6805P2	1K	64	0	8-Bit	—	No	20	0.1-1.0	28-P 28-FN	705P3	LVI Option
MC6805P6	2K	64	0	8-Bit	—	No	20	0.1-1.0	28-P	705P3	LVI Option
MC6805R2	2K	64	0	8-Bit	—	Yes	32	0.1-1.0	40-P 44-FN	705R3	LVI Option, Prog. Prescaler Option
MC6805R3	4K	112	0	8-Bit	—	Yes	32	0.1-1.0	40-P 44-FN	705R3	7-Bit Prescaler, LVI Option
MC6805R6	4K	112	0	8-Bit	—	Yes	32	0.1-1.0	40-P 44-FN	705R3	
MC6805S2	1K	64	0	16-Bit; 8-Bit	SPI	Yes	16	0.1-1.0	28-P	705S3	15-Bit Prescaler, LVI
MC6805S3	4K	104	0	2 8-Bit; 16-Bit	SPI	Yes	21	0.1-1.0	28-P	705S3	1 Extra 8-Bit Timer
MC6805U2	2K	64	0	8-Bit	—	No	32	0.1-1.0	40-P 44-FN	705U3	LVI Option
MC6805U3	4K	112	0	8-Bit	—	No	32	0.1-1.0	40-P 44-FN	705U3	7-Bit Prescaler LVI Option

ONE-TIME PROGRAMMABLE/EMULATOR MCUs

Motorola Part Number	EPROM	RAM	EEPROM	Timer	Serial	A/D	I/O	Bus Speed, MHz	Package†	Comments
MC68HC705B5	6K	176	0	16-Bit–2 IC, 2 OC, WDOG	SCI	Yes	32	0-2.1	56-B 52-FN	2 PWMs
XC68HC705C5	5K	176	128	16-Bit–1 IC, 1 OC, WDOG	SIOP	No	32	0-2.1	40-P 40-S 44-FN	10 mA Sink Port, LVPI
MC68HC705C8	8K	304	0	16-Bit–1 IC, 1 OC, WDOG	SPI, SCI	No	31	0-2.1	40-P 44-FN 40-S 44-FB	High Speed Versions Available
XC68HC705C9	16K	352	0	16-Bit–1 IC, 1 OC, WDOG	SPI, SCI	No	31	0-2.1	40-P 40-S 44-FN	
XC68HC705D9	16K	352	0	16-Bit–1 IC, 1 OC, WDOG	SCI	No	31	0-2.1	40-P 40-S 44-FN	5 PWMs, LED
XC68HC705E1	4K	368	0	15 stage multi-function, RTC, RTI, WDOG	—	No	20	0-2.1	28-S 28-P 28-DW	Internal PLL 32 kHz Clock
XC68HC705F6	4K	320	0	16-Bit–1 IC, 1 OC	SPI	No	26	0-2.1	42-B	
XC68HC705H2	2K	128	0	15 stage multi-function, RTC, WDOG	SIOP	No	16	0-2.1	40-P 44-FN	Dual LDMOS, PWMs, H-Bridge Drivers
MC68HC705J2	2K	112	0	15 stage multi-function, RTI, WDOG	—	No	14	0-2.1	20-P 20-DW 20-S	
XC68HC705L5	8K	256	0	16-Bit–1 IC, 1 OC 8-Bit–1 IC, 1 OC	SIOP, SPI	No	39	0-2.1	80-FU	160-Segment LCD
XC68HC705P9	2K	128	0	16-Bit–1 IC, 1 OC, WDOG	SIOP	Yes	21	0-2.1	28-P, 28-DW, 28-S	
XC68HC705T10	12K	320	0	16-Bit–1 IC, 1 OC, RTC	I^2C	Yes	28	0-2.1	56-B	
MC68705R3	4K	112	0	8-Bit	—	Yes	32	0-2.1	40-P 44-FN 40-S	7-Bit Prescaler, LVI Option, HMOS
MC68HC805B6	0	176	6K+256	16-Bit–2 IC, 2 OC, WDOG	SCI	Yes	32	0-2.1	52-FN	PWMs
XC68HC805C4	0	176	4K	16-Bit–1 IC, 1 OC	SPI, SCI	No	31	0-2.1	40-P 44-FN	Not for production. For emulation only.

MCU NEW PRODUCTS

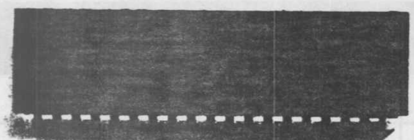
Part	Description	ROM	RAM	Samples*	Package†
M68HC05 Family:					
68HC05B16	68HC05B8 with 15K ROM, 352 RAM	15K	352	4Q92	56-B, 52-FN
68HC05C12	68HC05C4 with 12K ROM	12K	176	2Q92	40-P, 44-FB
68HC05C32	68HC05D24 with 32K ROM, 352 RAM	32K	352	4Q92	40-P, 44-FN
68HC05G1	68HC05 with A/D, SPI	8K	176	2Q92	56-B
68HC05I8	68HC05 with 2-SCI, 68K Interface	8K	172	2Q92	68-FU
68HC05K0	68HC05 with 0.5 ROM, 16-Pin	0.5K	32	2Q92	16-P, 16-DW
68HC05K1	68HC05K0 with 8 Byte Personality EPROM	0.5K	32	2Q92	16-P, 16-DW
68HC05L1	68HC05 with A/D, LCD, 2 Timers	4K	128	2Q92	56–B
68HC05L4	68HC05 with 2-Timers, LCD	8K	224	2Q92	64–B
68HC05L11	68HC05 with SPI, SCI, MMU, LCD	0	447	2Q92	100-FU
68HC05M6	68HC05 with VFD, 16-bit Timer	6K	208	2Q92	64-B
68HC05P2	68HC05 with MBUS, A/D	3K	96	2Q92	32-FB
68HC05P6	68HC05P9 with A/D, SIOP	4K	128	2Q92	28-P, 28-DW
68HC05P10	68HC05P7 with 4K ROM, Port Pullups	4K	128	2Q92	28-P, 28-DW
68HC05SC27	68HC05 Smart Card	16K	240	2Q92	Die
68HC05T3	68HC05 with A/D, 9 PWMs, OSD, SIOP	24K	512	2Q92	40-P
68HC05T10	68HC05 with 12K ROM, I^2C, 8 PWMs, A/D, OSD	12K	320	2Q92	56-B
68HC705G1	68HC05G1 EPROM Version	12K E	176	2Q92	56-B, 64-B
68HC705K1	68HC05K0/K1 EPROM Version	0.5 E	32	2Q92	16-P, 16-DW
68HC705L1	68HC05L1 EPROM Version	6K E	128	2Q92	56-B
68HC705P6	68HC05P6 EPROM Version	4.6K	176	3Q92	28-P
68HC705T3	68HC05T3 EPROM Version	24K E	512	2Q92	40-P
68HC705T4	68HC05T4 EPROM Version	6K E	96	2Q92	42-B

*Dates subject to change. Call product marketer to verify dates.

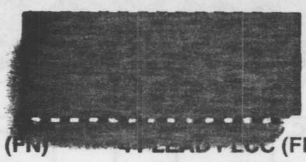
E = EPROM or OTPROM
EE = EEPROM

PREFERRED PACKAGE OPTIONS (ACTUAL SIZE)

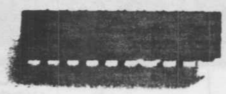
40-PIN DIP (P)
(100 mil PITCH)



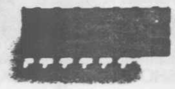
28-PIN DIP (P)
(100 mil PITCH)



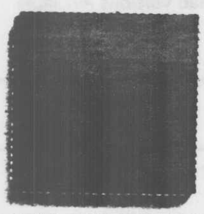
20-PIN DIP (P)
(100 mil PITCH)



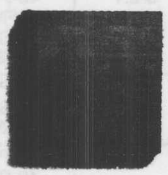
16-PIN DIP (P)
(100 mil PITCH)



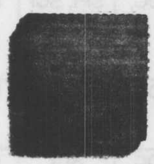
68-LEAD PLCC (FN)
(50 mil PITCH)



52-LEAD PLCC (FN)
(50 mil PITCH)

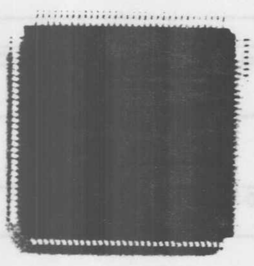


44-LEAD PLCC (FN)
(50 mil PITCH)

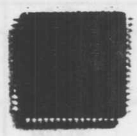


28-LEAD PLCC (FN)
(50 mil PITCH)

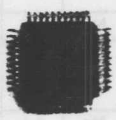
128-LEAD QFP (FU)
(0.8 mm PITCH)



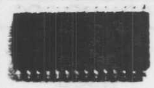
64-LEAD QFP (FU)
(0.8 mm PITCH)



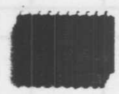
44-LEAD QFP (FB)
(0.8 mm PITCH)



28-LEAD SOIC (DW)
(50 mil PITCH)

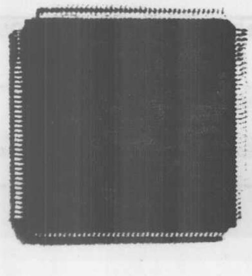


20-LEAD SOIC (DW)
(50 mil PITCH)

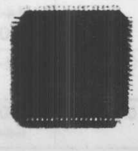


16-LEAD SOIC (DW)
(50 mil PITCH)

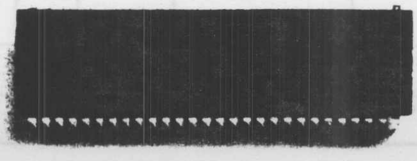
144/160 LEAD QFP (FT)
(0.65 mm PITCH)



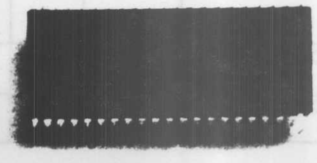
80-LEAD QFP (FU)
(0.65 mm PITCH)



56-PIN SDIP (B)
(70 mil PITCH)



42-PIN SDIP (B)
(70 mil PITCH)



DEVELOPMENT TOOLS

Devices	Evaluation Modules*	Evaluation Systems*	Programmer Boards	In-Circuit Simulator
MC68HC05A6	M68HC05EVM			
MC68HC05B4/B6	M68HC05EVM			
MC68HC705B5	M68HC05EVM		M68HC705B5PGMR	
MC68HC805B6	M68HC05EVM			
MC68HC05C2/C3/C4/C8/C9	M68HC05EVM			
MC68HC05C5, MC68HC705C5		M68HC05C5EVS		
MC68HC705C8	M68HC05EVM		M68HC05PGMR	
MC68HC805C4	M68HC05EVM			
MC68HC705D9	M68HC05EVM			
MC68HC05E1, MC68HC705E1		M68HC05E1EVS		
MC68HC05F6, MC68HC705F6	M68HC05F6EVM			
MC68HC05G8	M68HC05G8EVM			
MC68HC05H2, MC68HC705H2		M68HC05H2EVS		
MC68HC05J1		M68HC05P8EVS		
MC68HC705J2		M68HC05P8EVS	M68HC705J2PGMR	
XC68HC705K1				M68HC705KICS**
MC68HC05L5, MC68HC705L5		M68HC05L5EVS		
MC68HC05L6	M68HC05EVM			
MC68HC05L7/L9	M68HC05L9EVM			
MC68HC05M4	M68HC05M4EVM			
MC68HC05P1/P4/P7	M68HC05EVM	M68HC05P9EVS		
MC68HC05P9		M68HC05P9EVS		
MC68HC05P8		M68HC05P8EVS		
MC68HC705P9		M68HC05P9EVS	M68HC705P9PGMR	
MC68HC05T1/T2		M68HC05T2EVS		
MC68HC05T4	M68HC05T4EVM			
MC68HC05T7, MC68HC705T10	M68HC05T7EVM			
MC6805P2/P6, MC6805R2/R3, MC6805U2/U3, MC68705P3/P5, MC68705R3/R5, MC68705U3/U5	M68705EVM			

* EVSs and EVMs include an Integrated Development Environment (IDE) which contains an editor, assembler, hardware debugger, and simulator.

** Only $50 through June 30, 1992!

CDS8—COMPACT DEVELOPMENT SYSTEM

Devices	System*	Target Cables	MCU Adapter Boards
MC68HC05A6	M68CDS8HC05	M68CDS05DIP40	
MC68HC05B4/B6/B8	M68CDS8HC05	M68CDS05PLCC52	
MC68HC05705B5/805B6	M68CDS8HC05	M68CDS05PLCC52	M68CDS8ADPTR52
MC68HC05C2/C3/C4/C5/C8/C9/D9	M68CDS8HC05	M68CDS05DIP40/ M68CD805PLCC44	
MC68HC05705C8/805C4	M68CDS8HC05	M68CDS05DIP40/ M68CDS05PLCC44	M68CDS8ADPTR40
MC68HC05J1	M68CDS8HC05	M68CDS05DIP20	
MC68HC05705J2	M68CDS8HC05	M68CDS05DIP20	M68CDS8ADPTR28
MC68HC05P1/P4/P7/P9	M68CDS8HC05	M68CDS05DIP28P9	
MC68HC05P8	M68CDS8HC05	M68CDS05DIP28P8	
MC68HC05705P9	M68CDS8HC05	M68CDS05DIP28P9	M68CDS8ADPTR28

* The CDS8 features real-time non-invasive, in-circuit emulation with real-time trace which contains a full featured assembler, easy-to-use window-oriented hardware debugger.

MOTOROLA 1992 FISCAL CALENDAR

Microcontroller Electronic Bulletin Board
FREEWARE—(512) 891-FREE
(512) 891-3733

1st QUARTER

WK	Sa	Su	Mo	Tu	We	Th	Fr
	JANUARY						
					1	2	3
01	4	5	6	7	8	9	10
02	11	12	13	14	15	16	17
03	18	19	20	21	22	23	24
04	25	26	27	28	29	30	$\boxed{31}$
	FEBRUARY						
05	1	2	3	4	5	6	7
06	8	9	10	11	12	13	14
07	15	16	17	18	19	20	21
08	22	23	24	25	26	27	$\boxed{28}$
	MARCH						
09	29	1	2	3	4	5	6
10	7	8	9	10	11	12	13
11	14	15	16	17	18	19	20
12	21	22	23	24	25	26	27
13	28	29	30	31	1	2	$\boxed{3}$

2nd QUARTER

WK	Sa	Su	Mo	Tu	We	Th	Fr
	APRIL						
14	4	5	6	7	8	9	10
15	11	12	13	14	15	16	17
16	18	19	20	21	22	23	24
17	25	26	27	28	29	30	$\boxed{1}$
	MAY						
18	2	3	4	5	6	7	8
19	9	10	11	12	13	14	15
20	16	17	18	19	20	21	22
21	23	24	25	26	27	28	$\boxed{29}$
	JUNE						
22	30	31	1	2	3	4	5
23	6	7	8	9	10	11	12
24	13	14	15	16	17	18	19
25	20	21	22	23	24	25	26
26	27	28	29	30	1	2	$\boxed{3}$

3rd QUARTER

WK	Sa	Su	Mo	Tu	We	Th	Fr
	JULY						
27	4	5	6	7	8	9	10
28	11	12	13	14	15	16	17
29	18	19	20	21	22	23	24
30	25	26	27	28	29	30	$\boxed{31}$
	AUGUST						
31	1	2	3	4	5	6	7
32	8	9	10	11	12	13	14
33	15	16	17	18	19	20	21
34	22	23	24	25	26	27	$\boxed{28}$
	SEPTEMBER						
35	29	30	31	1	2	3	4
36	5	6	7	8	9	10	11
37	12	13	14	15	16	17	18
38	19	20	21	22	23	24	25
39	26	27	28	29	30	1	$\boxed{2}$

4th QUARTER

WK	Sa	Su	Mo	Tu	We	Th	Fr
	OCTOBER						
40	3	4	5	6	7	8	9
41	10	11	12	13	14	15	16
42	17	18	19	20	21	22	23
43	24	25	26	27	28	29	$\boxed{30}$
	NOVEMBER						
44	31	1	2	3	4	5	6
45	7	8	9	10	11	12	13
46	14	15	16	17	18	19	20
47	21	22	23	24	25	26	$\boxed{27}$
	DECEMBER						
48	28	29	30	1	2	3	4
49	5	6	7	8	9	10	11
50	12	13	14	15	16	17	18
51	19	20	21	22	23	24	25
52	26	27	28	29	30	$\boxed{31}$	

MONTH END - □ YEAR END - ☒

Definitions:

- DTMF —Dual-Tone Multi-Frequency
- IC —Input Capture
- I^2C —Inter-Integrated Circuit
- LVI —Low-Voltage Interrupt
- LVPI —Low Voltage Program Inhibit
- OC —Output Compare
- OSD —On-Screen Display
- PLL —Phase-Lock Loop
- PWM —Pulse Width Modulation
- RTC —Real-Time Clock
- RTI —Real-Time Interrupt
- SCI —Serial Communications Interface
- SIOP —Simple Serial I/O Port
- SPI —Serial Peripheral Interface
- VFD —Vacuum Fluorescent Display
- WDOG—Watch Dog Timer

†Package Definitions:

- B —Shrink Dual-in-Line Plastic
- DW —Small Outline (Wide-Body SOIC)
- FB —10x10 mm Quad Flat Pack (QFP)
- FN —Plastic Quad (PLCC)
- FS —Cerquad
- FT —28x28 mm Quad Flat Pack (QFP)
- FU —14x14 mm Quad Flat Pack (QFP)
- P —Dual-in-Line Plastic
- S —Cerdip (windowed or non-windowed)

8-BIT MPU/PERIPHERALS

Device	Pins	Package†	Part Description
MC146818	24	P	Real Time Clock, 50 Bytes RAM, Programmable Square Wave
MC146818A	24, 28	P, FN	Enhanced Version of the MC146818
MC146823	40, 44	P, FN	Three 8-Bit Ports, Handshake Control Logic
MC146805E2	40, 44	P, FN	CMOS 8-Bit Microprocessor
XC68HC68L9	80	FU	LCD Expansion to the HC05L9

Literature Distribution Centers:
USA: Motorola Literature Distribution; P.O. Box 20912; Phoenix, Arizona 85036.
EUROPE: Motorola Ltd.; European Literature Centre; 88 Tanners Drive, Blakelands, Milton Keynes, MK14 5BP, England.
JAPAN: Nippon Motorola Ltd.; 4-32-1, Nishi-Gotanda, Shinagawa-ku, Tokyo 141 Japan.
ASIA-PACIFIC: Motorola Semiconductors H.K. Ltd.; Silicon Harbour Center, No. 2 Dai King Street, Tai Po Industrial Estate, Tai Po, N.T., Hong Kong.

MOTOROLA

1ATX30081-5 PRINTED IN USA 4/92 IMPERIAL LITHO 85430 25,000 MCU YGACAA

M68HC11 M68300 Microcontrollers

Selector Guide 2Q92

MOTOROLA
Semiconductor Products Sector

Advanced Microcontrollers

M68HC11 (HCMOS)

Motorola Part Number	ROM	RAM	EEPROM	Timer	Serial	A/D	I/O	Bus Speed MHz	Temp Range (1)	Package †	POQ	EPROM Version	Port Replace/ Other
68HC11A0	0	256	0	16 bit - 3 IC, 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	22	0 - 2.0 0 - 3.0	C,V,M C	52 FN 48 P 64 FU	24 7 50	N/A	HC24
68HC11A1 (3)	0	256	512	16 bit - 3 IC, 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	22	0 - 2.0 0 - 3.0	C,V,M C	52 FN 48 P 64 FU	24 7 50	N/A	HC24
68HC11A7	8K	256	0	16 bit - 3 IC, 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	38	0 - 2.0 0 - 3.0	C,V,M C	52 FN 48 P 64 FU	24 7 50	711E9	
68HC11A8 (3)	8K	256	512	16 bit - 3 IC, 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	38	0 - 2.0 0 - 3.0	C,V,M C	52 FN 48 P 64 FU	24 7 50	711E9	
68HC11D0 (3)	0	192	0	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	No	14	0 - 2.0 0 - 3.0	C,V,M C	40 P 44 FN 44 FB	9 15 50	N/A	HC27
68HC11D3 (3)	4K	192	0	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	No	32	0 - 2.0 0 - 3.0	C,V,M C	40 P 44 FN 44 FB	9 15 50	711D3	
68HC11E0	0	512	0	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	22	0 - 2.0 0 - 3.0	C,V,M C	52 FN 64 FU	24 50	N/A	HC24
68HC11E1 (3)	0	512	512	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	22	0 - 2.0 0 - 3.0	C,V,M C	52 FN 64 FU	24 50	N/A	HC24
68HC11E8	12K	512	0	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	38	0 - 2.0 0 - 3.0	C,V,M C	52 FN 64 FU	24 50	711E9	
68HC11E9 (3)	12K	512	512	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	38	0 - 2.0 0 - 3.0	C,V,M C	52 FN 64 FU	24 50	711E9	
68HC811E2	0	256	2K	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	38	0 - 2.0	C,V,M	52 FN 48 P	24 7	N/A	HC24
68HC11F1	0	1K	512	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	30	0 - 3.0 0 - 4.0	C,V,M (2)	68 FN 80 FU	19	N/A	HC27 Chip Selects
68HC11K0	0	768	0	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	37	0 - 3.0 0 - 4.0	C,V,M C	84 FN	16	N/A	HC24 Chip Selects
68HC11K1 (3)	0	768	640	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	37	0 - 3.0 0 - 4.0	C,V,M C	84 FN	16	N/A	HC24 Chip Selects
68HC11K3	24K	768	0	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	62	0 - 3.0 0 - 4.0	C,V,M C	84 FN	16	711K4	Chip Selects
68HC11K4 (3)	24K	768	640	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	62	0 - 3.0 0 - 4.0	C,V,M C	84 FN	16	711K4	Chip Selects
68HC11L0	0	512	0	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	30	0 - 2.0 0 - 3.0	C,V,M C	64 FU 68 FN	50 19	N/A	HC24
68HC11L1 (3)	0	512	512	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	30	0 - 2.0 0 - 3.0	C,V,M C	64 FU 68 FN	50 19	N/A	HC24
68HC11L5	16K	512	0	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	46	0 - 2.0 0 - 3.0	C,V,M C	64 FU 68 FN	50 19	711L6	
68HC11L6 (3)	16K	512	512	16 bit - 3 or 4 IC, 4 or 5 OC, RTI, WDOG, Pulse Accumulator	SPI, SCI	Yes	46	0 - 2.0 0 - 3.0	C,V,M C	64 FU 68 FN	50 19	711L6	

(1) C: -40°C to 85°C, V: -40°C to 105°C, M: -40°C to 125°C
(2) 0°C to 70°C at this time.
(3) Part available in 3 volt version.

M6801 and M6803 (HMOS)

Motorola Part Number	ROM	RAM	EEPROM	Timer	Serial	A/D	I/O	Bus Speed, MHz	Package †	EPROM or EEPROM Version	Comments
6801	2048	192	0	16 bit: 1IC, 1OC	SCI	No	29	0.5 - 2.0	40 P	68701	
6803	0	192	0	16 bit: 1IC, 1OC	SCI	No	13	0.5 - 2.0	40 P	N/A	
6801U4	4096	256	0	16 bit: 2IC, 3OC	SCI	No	29	0.5-1.25	40 P	68701U4	
6803U4	0	256	0	16 bit: 2IC, 3OC	SCI	No	13	0.5-1.25	40 P	N/A	

M68HC16 and M68300 (HCMOS)

Motorola Part Number	ROM	RAM	EEPROM	Timer / DMA	Serial	A/D	I/O	Bus Speed, MHz	Package †	POQ	Comments
68HC16Z1	0	1K	0	General Purpose Timer: 3 or 4 IC, 4 or 5 OC, Pulse Accumulator, 2 PWM, RTI, WDOG	Queued SPI, SCI	Yes	50	0 - 16.8	132 FC 132 FD 144 FM 144 FV	2, 36	External Bus 12 Chip Selects Synthesized Clock
68330	0	0	0	RTI, WDOG	No	No	16	0 - 16.8	132 FC 132 FE	2, 36	Available from High Performance MPU Div 32 Address Lines 2 Chip Selects
68331	0	0	0	General Purpose Timer: 3 or 4 IC, 4 or 5 OC, Pulse Accumulator, 2 PWM, RTI, WDOG	Queued SPI, SCI	No	43	0 - 16.8	132 FC 132 FD 144 FM 144 FV	2, 36	External Bus 12 Chip Selects Synthesized Clock
68332	0	2K	0	TPU: 16 Intelligent microcoded channels, RTI, WDOG	Queued SPI, SCI	No	47	0 - 16.8	132 FC 132 FD 144 FM 144 FV	2, 36	External Bus 12 Chip Selects Synthesized Clock
68340	0	0	0	2 16 bit Timers w/ 8 bit prescaler, RTI, WDOG 2 ch 32 bit DMA	2 ch UART	No	28	0 - 16.8	144 FE 144 RP	2, 36	Available from High Performance MPU Div 32 Address Lines 2 Chip Selects

ONE–TIME PROGRAMMABLE and REPROGRAMMABLE MCUs

Motorola Part Number	EPROM	RAM	EEPROM	Timer	Serial	A/D	I/O	Bus Speed, MHz	Package †	POQ	Comments
68HC711D3	4K	192	0	16 Bit – 3 or 4 IC 4 or 5 OC Pulse Accumulator, RTI, WDOG	SPI, SCI	No	32	0 – 3.0	40 P 44 FN 40 S 44 FS	9 50 9 50	Multiplexed Bus
68HC711E9	12K	512	512	16 Bit – 3 or 4 IC 4 or 5 OC Pulse Accumulator, RTI, WDOG	SPI, SCI	Yes	38	0 – 3.0	52 FS 52 FN	24 24	Multiplexed Bus EEPROM Block Protect
68HC711K4	24K	768	640	16 Bit – 3 or 4 IC 4 or 5 OC, 4 PWM Pulse Accumulator, RTI, WDOG,	SPI, SCI	Yes	62	0 – 4.0	84 FN 84 FS	16 16	Non–Muxtiplexed Bus EEPROM Block Protect
68HC711L6	16K	512	512	16 Bit – 3 or 4 IC 4 or 5 OC Pulse Accumulator, RTI, WDOG	SPI, SCI	Yes	46	0 – 3.0	64 FU 68 FN 68 FS	50 19 19	Multiplexed Bus EEPROM Block Protect

8–BIT MPU/PERIPHERALS

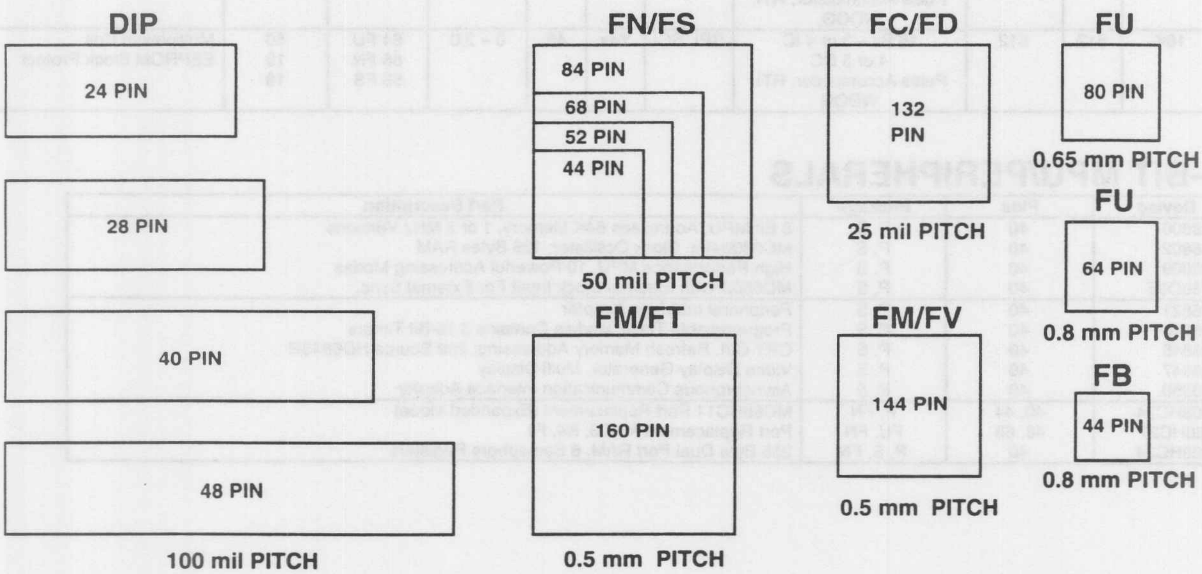
Device	Pins	Package	Part Description
MC6800	40	P, S	8 Bit MPU, Addresses 64K Memory, 1 or 2 MHz Versions
MC6802	40	P, S	MC6800+Int. Clock Ocsillator; 128 Bytes RAM
MC6809	40	P, S	High Performance MPU, 10 Powerful Addressing Modes
MC68O9E	40	P, S	MC6809 With External Clock Input For External Sync.
MC6821	40	P, S	Peripheral Interface Adapter
MC6840	40	P, S	Programmable Timer Module Contains 3 16-Bit Timers
MC6845	40	P, S	CRT Ctrl, Refresh Memory Addressing; 2nd Source HD6845R
MC6847	40	P, S	Video Display Generator, Multi Display
MC6850	40	P, S	Asynchronous Communication Interface Adaptor
MC68HC24	40, 44	P, FN	MC68HC11 Port Replacement (Expanded Mode)
XC68HC27	46, 68	FU, FN	Port Replacement for D3, K4, F1
MC68HC34	40	P, S, FN	256 Byte Dual Port RAM, 6 Semaphore Registers

NEW PRODUCTS

Motorola Part Number	Description	ROM	RAM	Samples*	Package†
68HC11E20	Expanded E9	20K	768	2Q92	52 FN 64 FU
68HC11G5	4 PWM, Event Counter, 10 bit A/D, SPI, SCI	16K	512	Now	84 FN
68HC11G7	4 PWM, Event Counter, 10 bit A/D, SPI, SCI	24K	512	Now	84 FN
68HC711G5	4 PWM, Event Counter, 10 bit A/D, SPI, SCI 16K EPROM	0	1024	2Q92	84 FN 84 FS
68HC11M2	4 PWM, 8 ch 8 bit A/D, 4 ch DMA Math Co–processor, 2 SPI, SCI	32K	1280	3Q92	84 FN
68HC711M2	4 PWM, 8 ch 8 bit A/D, 4 ch DMA Math Co–processor, 2 SPI, SCI 32K EPROM	0	1280	2Q92	80 FU
68HC11N4	6 PWM, 12 ch 8 bit A/D, 2 ch 8 bit D/A Math Co–processor, SPI, SCI 640 EEPROM	24K	768	1Q92	80 FU
68HC711N4	6 PWM, 12 ch 8 bit A/D, 2 ch 8 bit D/A Math Co–processor, SPI, SCI 640 EEPROM, 24K EPROM	0	768	Now	84 FN 84 FS
68HC11P2	4 PWM, 8 ch 8 bit A/D, SPI, 3 SCI, PLL Clock 640 EEPROM	32K	1024	3Q92	84 FN
68HC711P2	4 PWM, 8 ch 8 bit A/D, SPI, 3 SCI, PLL Clock 640 EEPROM, 32K EPROM	0	1024	1Q92	84 FN 84 FS
68HC11KA4	68HC11K4 without MMU and Chip Selects	24K	768	1Q92	84 FN
68HC711KA4	68HC711K4 without MMU and Chip Selects, 24K EPROM	0	768	2Q92	84 FN
68HC16Y1	CPU16, TPU, General Purpose Timer 8 ch 10 Bit A/D, SPI, 2 SCI	48K	2048	2Q92	160 FT 160 FM
68HC16Z2	CPU16, General Purpose Timer 8 ch 10 Bit A/D, Queued Serial Module	8K	2048	2Q92	132 FC 132 FD
68F333	CPU32, 64K Flash EEPROM, TPU, QSM, ADC, SCIM	0	4096	2Q92	160 FT 160 FM

* Dates subject to change. Call product marketer to verify dates.

PREFERRED PACKAGE OPTIONS (ACTUAL SIZE)



DEVELOPMENT TOOLS

Devices	Evaluation Modules /Boards/Systems					
	M68HC11EVB	M68HC711D3EVB	M68HC11EVBU	M68HC11EVM	M68HC11F1EVS	M68HC11K4EVS
MC68HC11A0/A1/A7/A8	√		√	√		
MC68HC11D0/D3		√		√		
MC68HC711D3		√		√		
MC68HC11E0/E1/E8/E9	√		√	√		
MC68HC711E9			√	√		
MC68HC811E2	√		√	√		
MC68HC11F1					√	
MC68HC11K0/K1/K3/K4						√
Documentation	BR278	BR737	BR736	BR266	BR706	

Devices	M68HC11L6EVS	M68HC16Z1EVB	M68331EVK	M68331EVS	M68332EVK	M68332EVS
MC68HC11L0/L1/L5/L6	√					
MC68HC16Z1		√				
MC68331			√	√		
MC68332					√	√
Documentation			BR734	BR734	BR734	BR734

IDE — Integrated Development Environment is included with HC11 EVM/EVS products.
The MC6801, MC6801U4, MC68701, MC68701U4, MC6803 and MC6803U4 are supported by the M68701EVM.

COMPACT DEVELOPMENT SYSTEMS

System	Description	Documentation	Available
M68CDS11	Compact Development System for the M68HC11 Family	CDS11	4Q92*
M68CDS16	Compact Development System for the M68HC16 Family	CDS16	3Q92*

* Dates subject to change. See E01 Screen "AMCUDEV" (WACCIMS) and MCU Toolbox for third party support.

68332 THIRD PARTY DEVELOPMENT SYSTEMS

System	Description	Documentation	Available
H64700A	Hewlett Packard Emulator/Analyzer 800-447-3282	Yes	NOW
HMI-200-68300	Huntsville Microsystem Emulator 205-881-6005	Yes	NOW

Definitions:

- ADC - Analog to Digital Converter Module
- A/D - Analog to Digital Converter
- CPU16 - 16 bit Central Processing Unit
- CPU32 - 32 bit Central Processing Unit
- D/A - Digital to Analog Converter
- DMA - Direct Memory Access
- DTMF - Dual–Tone Multi–Frequency
- IC - Input Capture
- IIC - Inter–Integrate Circuit
- MCCI - Multi–Channel Communication Interface
- PLL - Phase Lock Loop
- OC - Output Capture
- POQ - Preferred Order Quantity multiple
- PWM - Pulse Width Modulation
- QSM - Queued Serial Module (SCI + Queued SPI)
- RTC - Real–Time Clock
- RTI - Real–Time Interface
- SCI - Serial Communication Interface
- SCIM - Single Chip Integration Module
- SIM - System Integration Module
- SPI - Serial Peripheral Interface
- TPU - Time Processing Unit
- UART - Universal Asynchronous Receiver/Transmitter
- WDOG - Watch Dog Timer

†Package Definitions:

- FB - 10x10 mm Quad Flat Pack (QFP)
- FC - Fine Pitch Plastic Quad Flat Pack (PQFP)
- FD - Plastic Quad Flat Pack in Molded Carrier Ring
- FE - Ceramic Quad Flat Pack (CQFP)
- FM - Molded Carrier Ring (MCR)
- FN - Plastic Leaded Chip Carrier (PLCC)
- FS - Windowed Cerquad (Ceramic LCC)
- FT - 28x28mm Quad Flat Pack (QFP)
- FU - 14x14mm Quad Flat Pack (QFP)
- FV - 20x20 mm Quad Flat Pack (QFP)
- L - Ceramic
- P - Dual–in–Line Plastic
- S - Cerdip (windowed and non–windowed)

Motorola / Aptronix Fuzzy Logic Tools

Part Number	Price	Description
FLEDKT00	$295	Fuzzy Logic Educational Kit Only
	$195	(Special offer, before August 31, 1992)
FLEDKT05*	$600	Fuzzy Logic Educational Kit bundled with HC05EVM
FLEDKT11*	$600	Fuzzy Logic Educational Kit bundled with HC11EVM
M68HXBFIDS	$1495	Aptronix Fuzzy Inference Development Environment (FIDE) Software

Each Educational Kit includes :

(1) Computer-Based Tutorial Program, (2) Demo Version of FIDE, (3) Freeware Fuzzy Tools, (4) Article Reprints and (5) Hawaii Contest Details.

*** Note : Only limited quantities available**

MOTOROLA Semiconductor Products Sector *Advanced Microcontrollers*

Authorized Motorola Distributors (Toronto) :

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Electro Sonic	(416) 494-1666
Future Electronics	(416) 612-9200
Hamilton/Avnet	(416) 564-6060